Particle Size Distributions

Selective Laser Melting (SLM) melts powder spread

Ball milling refines particle size and incorporates the

The MCrAl powders are currently used in thermal

Additively manufactured MCrAl(Y) powders are

NiCrAl and 0.6 wt% yttria powder are milled via two

milling methods: Planetary ball milling at a low RPM

with ¼” stainless steel spheres & attritor ball milling

at a high RPM with ¼” WC spheres. Powders were

sieved post-milling using 325 and 635 mesh.

Morphologi Procedure:

• Diameter, circularity, intensity, etc. gathered

• Automated optical microscope images powders

• Sample dispersed over slide

• Degassed 12 hours, 250˚C

• Cross-sectional examination to determine yttria

  dispersion in the core of the particles.

Energy Dispersive X-ray Spectroscopy

Element Atomic %

Ni 55
Cr 17
O 17
Al 10
Y 1

Elemental analysis shows that yttria is

being fractured and dispersed on the

NiCrAl particle surfaces. (τ = 6 a.u.)

Acknowledgements

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Experimental Procedure

Ball Milling

NiCrAl and 0.6 wt% yttria powder are milled via two

milling methods: Planetary ball milling at a low RPM

with ¼” stainless steel spheres & attritor ball milling

at a high RPM with ¼” WC spheres. Powders were

sieved post-milling using 325 and 635 mesh.

Characterization and Preparation Sites

NASA Glenn Purdue University

Powder milling BET Surface Area
Separation from media SEM
Initial sieving Morphologi analysis
Morphologi gathering BET Procedure:

• Degassed 12 hours, 250˚C

Morphologi Procedure:

• Sample dispersed over slide

• Automated optical microscope images powders

• Diameter, circularity, intensity, etc. gathered

Results & Discussion

Sieving

Scanning Electron Microscopy

Starting Materials: Yttria Powder (<10 μm) and NiCrAl Powder (5-50 μm)

Cycles of welding and fracture occur as milling time is

increased from τ = 0 to 10 a.u.

Increasing Planetary Milling Time

Welding and fracture occur faster for attritor milling

compared to orbital milling

Increasing Attritor Milling Time

Attritor ball milling showed higher surface area at

lower milling times compared to planetary ball milling.

Welding occurred at τ = 0.5 a.u. followed by fracture at τ = 1.0 a.u. in the attritor. Planetary ball milling

experienced cyclic welding and fracture. Planetary

ball milling had less variation in surface area compared to attritor ball milling at lower hours.

Results & Discussion (cont.)

Morphologi Particle Size Distributions

• Cycling through large and small average diameter in both methods

• Two sizes of particles form with attrition milling

• Attrition milling takes place over 1/10 the time

• Attrition milling takes place over 1/10 the time

• Two sizes of particles form with attrition milling

• Attritor milling experienced a full cycle of welding

  and fracture in 80% less time than planetary milling

• Yttria was shown to disperse evenly on the particle

  surfaces.

• More cycles of welding and fracture were

  observed for planetary milling.

Conclusions

• Multiple cycles of welding and fracture were

  observed for planetary milling.

• One cycle of welding and fracture was observed for

  attritor milling.

• Attritor milling experienced a full cycle of welding

  and fracture in 80% less time than planetary milling.

• Yttria was shown to disperse evenly on the particle

  surface (τ = 6 a.u).

Future work

• Analysis of milling time for the planetary ball mill

  should be explored, to fill in intermediate times.

• Examination of an increased milling speed to further

  reduce time while maintaining similar trends.

• Investigate potential oxidation in milling via X-Ray

  Diffraction.

• Cross-sectional examination to determine yttria

  dispersion in the core of the particles.

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